THE TEMPERATURE OF *ECHIDNA ACULEATA*.*

By H. S. Halcro Wardlaw, B.Sc.

(From the Physiological Laboratory of the University of Sydney.)

(With eight Text-figures.)

Introduction.—The study of the morphology of Echidna has led to its being classified with the most primitive of mammals. This fact has, perhaps, given rise to the supposition that the functional activities of the animal would share the primitive characters of its structure; and, indeed, Chapman(**4**) has shown that the behaviour of the muscle of the Echidna towards stimuli resembles more that of the muscle of cold-blooded animals such as the frog, than that of typical mammalian muscle. The observations which had, up to the present, been made of the temperature of Echidna were interpreted as further justifying this supposition.

The temperatures of reptiles lie within a few tenths of a degree of that of the surrounding air [Pembrey(**10**), Richet(**11**), Soetbeer(**14**)]. They vary, therefore, from day to day with the changes of the external temperature.

The temperatures of birds and of nearly all mammals (including marsupials) are subject to little variation (Pembrey, Richet, *loc. cit.*), and are maintained at levels (36°-45°C.), above which, in most parts of Australia, the temperature of the air rises only during a short season of the year [Hunt(**5**)].

The temperature of Echidna, however, was found to be considerably lower and more variable than that of other mammals. N. de Miklouho-Maclay(**9**), who appears to have been the first to observe the temperature of this animal (1879), found the cloacal

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* The work, of which this paper is an account, was carried out in the year 1914, during the author's tenure of a Science Research Scholarship at the University of Sydney.

temperatures of two specimens to be 28·3° and 26·95°C. R. von Lendenfeld(**6**) gives the ordinary blood-temperature of the animal as 28°C., although he says it may rise as high as 35°C. Semon(**13**) found that the cloacal temperatures of the seven Echidnas, which he was able to observe, ranged from 26·5° to 34·0°C., whilst Sutherland(**15**), observing fourteen animals, found temperatures ranging from 22° to 36°C. The two latter observers recorded the temperatures of the air as well as those of the animals. The only conclusions to be drawn from the above small number of observations seem to be those expressed by Semon, that Echidna is not strictly to be classed either with poikilothermal or with homoiothermal animals; it has a body-temperature which stands in no direct relation to the temperature of the external air, but which undergoes uncommonly large variations.

Later, C. J. Martin(**7**) studied the behaviour of the temperature of Echidna, when the external temperature was rapidly varied in a definite and regular manner. Under these circumstances, it was shown that the temperature of Echidna undoubtedly depended on that of the surroundings. In experiments on three animals, for example, when the temperature of the surroundings rose from 5° to 35° in 6-7 hours, the temperature of the Echidnas rose from 25·5° to 34·8°, or 9·3°C., from 27·6° to 40·0°, or 12·4°C., and from 29·1° to 37·1°, or 8·0°C., respectively. It must be noted, however, that under circumstances such as these even the temperatures of higher mammals showed a degree of dependence on the external temperature much greater than usual. In the case of a rabbit, when the air-temperature fell from 40° to 5°, or 35°C., in about five hours, the temperature of the animal fell from 41·6° to 37·5°, or 4·1°C., in the same time. In the case of a cat, when the same fall in the external temperature occurred in an equal time, the temperature of the animal fell from 39·9° to 38·5°, or 1·4°C. The variations of the temperatures of reptiles (blue-tongued lizards) in similar experiments followed exactly those of the temperature of the surrounding air.

Under the conditions of these experiments, therefore, Echidna behaved in a manner intermediate, with regard to the regulation of its temperature, between that of reptiles and that of mammals;

and Martin concluded that Echidna is the lowest on the scale of warm-blooded animals.

But there is a class of mammals whose temperatures are at times subject to very great variations – the class of hibernants. The members of this class are not confined to any one group of animals, and among them is to be numbered Echidna (N. de Miklouho-Maclay, Martin, *loc. cit.*). During the winter-months, animals of this class allow their temperatures to sink towards that of the external air, and behave like cold-blooded animals for periods of varying duration.

As to the temperatures of these animals outside of the periods of hibernation, the data available are rather few in number, and different observers are not unanimous in their opinions. Pembrey (*loc. cit.*) states that, with regard to temperature, the behaviour of hibernants in their waking-state is practically the same as that of other warm-blooded animals. Merzbacher(**8**), on the other hand, is of the opinion that the temperature of hibernants in their waking-state is rather lower than that of other mammals, and is subject to much greater variations. He cites his own observations and those of Saissy(**12**), who gives the waking-temperature of the bat as 31°C; Berthold(**3**), who states that the normal waking-temperature of the dormouse is 29·7°C.; Barkow(**2**), who observed temperatures ranging from 25° to 35°C. in the case of a waking hedgehog; and of several other investigators in support of this view. A quotation from Barkow may be given as summarising their position: "Obgleich die Tiere ausserhalb des Winterschlafes zu den Warmblütigen gehören, so zeigt die Lebenswärme doch bei verminderter allgemeiner Tätigkeit, wie während des gewöhnlichen Schlafes, bei Abmagerung, oder sonstiger Krankheit, *grosse Neigung zum Sinken.*" Athanasiu(**1**), however, while admitting that the waking-temperatures of hibernants are perhaps slightly lower than those of other mammals, throws doubts on the reliability of the low figures given by some of the above observers, and points out how extremely limited is our knowledge of the temperatures of hibernants in their active state, and how necessary are new investigations to give us satisfactory information on this question.

In view of this incomplete state of our knowledge of the waking-temperatures of other hibernants, therefore, the conclusion that Echidna is the lowest on the scale of warm-blooded animals seems hardly justified. Anatomically, Echidna is indeed the most primitive of mammals, but between the anatomical classification of animals and their physiological functions there is not necessarily a direct relation. With regard to temperature, for example, this is well illustrated by a comparison of birds with reptiles and with mammals. As far as their structure is concerned, birds are much more closely related to reptiles than to mammals, and yet their behaviour with regard to temperature is quite different from that of reptiles, and very similar to that of mammals.

The aim of the present work has been to collect a series of observations of the body-temperature of Echidna under conditions which, although they can hardly be called natural, yet underwent no arbitrary, regular variations. The endeavour has also been made, by collecting a large number of data over fairly long periods and at different times of the year, to obtain material from which a more comprehensive idea of the behaviour of Echidna, with regard to temperature, might be gathered.

It may be stated here (i.) that the Echidnas under my observation hibernated only for very short periods at a time during the winter, (ii.) that, outside the periods of hibernation, their temperature kept in the neighbourhood of a value (30°C.) which is considerably lower than that of the average temperature of the majority of mammals, and (iii.) that the temperature of the animals was subject to comparatively large variations, and seemed to be affected, to some extent, by the temperature of the air.

Methods.—The observations recorded in this paper were made upon ten Echidnas, all males, and varying in weight from about 600 to about 2000 gms. The animals were kept in a shed of fibro-cement, the floor of the shed being of concrete, and having upon it a layer of sawdust about 5 cm. thick. For the first three weeks during which observations were made, the animals were fed upon bread and milk; for the remainder of the time, upon eggs beaten up with milk to which a little sodium citrate had been added to hinder coagulation. These animals are apt to so gorge themselves upon milk (they are able to drink as much as 30% of their body-weight of it) that, if clotting be allowed to take place unhindered, a solid mass, which digests very slowly, is formed in the stomach and eventually causes death.

Of the ten Echidnas under observation, Nos.1-7 were caught in Autumn, Nos.8-10 in Spring. These animals survived for varying lengths of time, after coming under observation, as set forth in tabular form below.

Caught in Autumn (April) 1914.	Caught in Spring (October) 1914.
No.1 lived for 37 days.	No.8 lived for 10 days.
No.2 lived for 75 days.	No.9 lived for 18 days.
No.3 lived for 61 days.	No.10 lived for 32 days.
No.4 lived for 32 days.	
No.5 lived for 103 days.	
No.6 still living.	
No.7 lived for 97 days.	

It will be noticed that the animals captured in Autumn lived, on the average, much longer than those taken in Spring. No.6 had been living in captivity for about twelve months at the time of writing. The death of one of the animals was due to acute peritonitis. What caused the death of the others is not known, although *post mortem* examinations showed the presence of infarcts in the liver in several cases. The animals were all rather emaciated before they died.

The body-temperatures of the animals were observed by inserting the bulb of a thermometer, graduated in tenths of a degree Centigrade, through the cloaca into the rectum, and reading off the temperature *in situ* to the nearest tenth of a degree after the lapse of two minutes, the time required for the mercury to become steady. The errors of the thermometers used were determined by reference to standard instruments, and the necessary corrections made to the readings. The animals were held up by a hind leg while the temperature was being observed. Difficulty was experienced at first in getting the thermometer into the rectum, owing to the rolling-up of the animals, but they soon became accustomed to handling, and then offered little resistance.

The temperatures of the animals were observed during two periods of the day, in the morning between 10 a.m. and 11 a.m., and in the afternoon between 2 p.m. and 3 p.m. The temperature of the air in the animals' shed, at a height of about 120 cm. from the floor, was always read just before taking the temperature of the animals. It should be remarked that the temperature of the air above the animals may be considerably different from that of the sawdust covering the floor of the shed. On one hot day, for example, the temperature of the air was 37·4°C., whilst that of the sawdust was only 21·9°C.

Results —The following is a tabular record of the observations made.

TABLE i.

Autumn and winter temperatures of Echidna.

Date.	Time.	Air-temp.	Temperature of Echidna						
			No.1.	No.2.	No.3.	No.4.	No.5.	No.6.	No.7.
30/4	10.15	20·2	30·8	29·8	31·6	29·1	31·6	28·3	28·5
	3.10	23·7	32·5	31·8	34·0	33·7	34·2	—	32·9
1/5	10.30	20·2	29·3	29·5	30·3	26·5	29·4	30·0	—
	2.30	22·2	31·8	32·4	33·3	30·9	33·4	32·0	33·0
4/5	11.0	20·2	30·0	31·9	30·1	25·9	30·3	29·9	30·2
	2.15	20·7	32·2	30·9	32·7	30·4	33·4	32·7	32·7
5/5	10.30	18·4	29·0	32·1	28·9	25·6	30·5	29·3	29·8
	2.30	20·4	31·6	31·3	32·7	30·2	33·7	30·8	32·9
6/5	10.30	18·6	27·7	30·7	31·2	23·2	29·7	29·0	29·8
	2.30	20·8	31·2	31·8	32·5	28·7	33·4	31·6	33·1
7/5	10.30	18·6	27·4	30·5	29·7	23·8	30·4	29·1	28·8
	2.0	19·8	29·8	32·9	33·2	29·4	33·3	30·3	32·5
8/5	10.15	20·3	26·8	30·3	30·4	25·1	29·3	29·3	29·4
	2.15	20·7	27·6	33·2	33·4	29·9	33·4	32·0	33·2
11/5	10.15	17·7	28·2	29·4	29·1	24·1	30·0	29·0	28·2
	2.30	19·9	31·4	32·9	33·4	29·0	33·3	32·0	—
12/5	10.30	17·6	29·2	30·0	27·4	25·0	29·4	28·6	29·9
	2.45	20·2	32·1	33·2	32·7	28·9	33·6	32·2	32·8
14/5	10.45	18·7	27·6	29·8	30·2	23·8	30·3	30·9	29·9
	3.15	19·7	32·1	33·4	32·8	29·0	33·5	33·5	33·3
15/5	10.45	17·2	28·8	30·5	26·1	24·9	29·3	29·7	29·5
	2.45	19·7	31·9	31·8	31·9	28·2	31·6	32·5	—
18/5	11.0	19·3	27·4	31·2	31·8	19·6	31·0	30·3	Lost
	3.0	18·3	31·0	32·4	33·2	21·5	33·1	32·5	
19/5	10.45	16·5	21·5	30·3	—	16·4	31·2	29·7	
	3.15	18·2	27·6	33·1	—	17·4	32·8	32·4	
20/5	10.30	17·3	21·5	30·0	26·9	16·6	29·6	28·6	20·0
	2.30	17·8	26·6	33·0	31·8	17·1	32·8	32·3	31·2
21/5	11.0	15·3	25·1	30·0	27·2	16·4	29·2	28·9	23·4
	2.45	17·0	28·9	32·6	32·0	22·8	32·0	32·1	29·2

TABLE i.—*Continued.*

Date.	Time.	Air-temp.	Temperature of Echidna						
			No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.
22/5	10.30	16·4	26·6	29·0	27·0	24·6	31·5	29·6	26·1
	2.45	17·2	30·9	33·1	32·4	28·8	33·6	32·6	32·1
25/5	10.15	14 8	15·0	29·2	19·2	14·8	26·8	30·0	14·8
	2.30	—	Hibernating, not disturbed.	33·2	30·6	Hibernating, not disturbed.	32·7	32·3	Hibernating, not disturbed.
26/5	10.30	16·1		29·3	26·2		29·6	27·1	
	—	—		—	Hibernating, not disturbed.		—	—	
27/5	10.30	13·2		25·1			18·0	25·3	
	3.0	14·1		32·5			31·1	Hurt, not disturbed.	
28/5	10.30	11 9		28·5			25·3		
	2.15	15·9		32·8			32·2		
29/5	10.30	13·7		26·1			18·3		
	—	16·6		32·9			—		
1/6	11.15	14·8	23·6	30·6	22·8	dead	29·5	22·2	28·8
	2.45	16·3	23·5	32·4	27·8	...	27·2	29·9	32·6
2/6	10.15	12·9	15·7	25·2	15·8	...	17·1	30·0	31·7
	2.45	17·2	16·2	32·5	19·1	...	16·9	30·4	33·0
3/6	10.15	12·8	13 5	25·5	14·8	...	12·8	23·8	21·9
	2.30	16 2	15·2	32·5	18·8	...	14·7	31·0	31·7
4/6	10.30	11·2	12·4	19·4	13·9	...	11·1	18·3	15·1
	2.45	16·0	14·5	31·8	21·7	...	13·9	29·5	18·9
5/6	10.30	13·3	dead	20·2	20·3	...	25·7	29·1	17·2
	2.45	16·9	...	30·8	32·1	...	32·0	31·5	31·0
9/6	11.0	13 7	...	20·9	17·9	...	19·6	17·7	19·4
	2.15	17·2	...	30·9	22·0	...	29·0	22·3	20·7
10/6	10.45	13·4	...	26·1	14·9	...	16·5	17·2	16·1
	2.30	16·5	...	32·5	15·8	...	29·1	29·5	15·8
11/6	10.15	13·2	...	30·4	13 5	...	25·3	29·6	13·8
	2.15	15·5	...	33·1	14·8	...	26·5	32·0	26·8
12/6	10.15	11·8	...	29·6	12·4	...	25·3	23·4	30·0
	2.15	15·4	...	32·7	14·7	...	27·8	30·5	32·0
15/6	10.30	12·0	...	14·8	11·9	...	28·8	13·5	13·3
	2.30	15·5	...	21·9	14·7	...	31·2	25·5	14·6
16/6	10.45	12·9	...	28·9	13·3	...	30·6	29·8	32·4
	2.30	14·3	...	33·1	14·3	...	31·5	31·6	32·1
17/6	10 30	12·9	...	20·9	13·2	...	29·7	14·4	20·6
	2.15	13·6	...	19·7	13·5	...	32·0	14·0	18·1
18/6	10-45	13·7	...	14·9	13·4	...	28·9	14·3	13·9
	2.15	14·8	...	15·2	18·2	...	31·6	25·1	14·8
19/6	10.45	13·7	...	24·1	20·2	...	30·6	28·8	13·8
	—	—	...	—	—	...	—	—	—
22/6	10.30	12·5	...	18·1	13·3	...	30·2	28·1	12·4
	2.0	13·8	...	29·5	15·3	...	32·6	32·0	13·7
23/6	10.15	10·9	...	24·3	13·0	...	30·3	28·7	31·9
	2.30	15 3	...	32·2	16·4	...	32·9	32·3	32·7
24/6	10.30	12·1	...	27·4	17·5	...	20·6	25·0	18·4
	2.30	15·9	...	33·0	16·6	...	32·8	31·5	15·9
25/6	10.45	13·6	...	28·8	14·6	...	29·6	27·7	13·5
	2.30	15·5	...	32·9	14·9	...	32·5	31·7	14·6
26/6	10.45	15·5	..	30·8	15·1	...	30·2	28·4	14·3
	2.30	16·2	...	30·5	15·7	...	32·6	30·1	15·2

TABLE i.—*Continued.*

Date.	Time.	Air-temp.	Temperature of Echidna						
			No.1.	No.2.	No.3.	No.4.	No.5.	No.6.	No.7.
30/6	10.15	16·5	...	25·3	dead	...	31·6	28·5	14·9
	2.30	16·0	...	28·8	...	...	29·3	31·3	19·0
1/7	10.45	14·2	...	19·8	...	...	28·3	21·1	29·5
	—	—	...	—		...	—	—	—
2/7	10.45	14·8		18·9	...	...	29·6	14·8	23·8
	2.15	14·5	...	19·9	...	...	33·0	15·9	21·2
3/7	10.30	15·5		20·0	...		30·3	31·6	18·9
	2.30	16·4	...	21·4		..	33·0	32·7	17·9
6/7	10.30	14·8	...	24·7	...	...	30·0	29·2	13·6
	2.0	15·9		25·0	...		32·6	32·1	14·7
7/7	10.15	13·8		18·1	...	...	29·7	28·5	13·9
	2.1	15·8	...	17·1	...	..	31·7	31·3	14·3
8/7	10.30	10·6	..	10·9	...	...	30·0	13·3	11·8
	2.15	12·4	.	11·5	..		32·9	18·5	11·6
9/7	10.30	12·1	...	11·4	...	...	28·6	16·3	11·1
	2.0	14·0	...	13·3		...	32·3	31·3	12·4
10/7	10.30	10·6		10·4	...		28·2	24·7	10·1
	2.30	12·5	...	11·3	...		31·9	29·0	10·9
13/7	10.30	9·9	.	dead	...	...	29·3	10·7	32·0
	2.45	12·2	...		...		32·4	11·2	32·4
14/7	10.15	10·6	...	...	...	...	28·4	9·9	18·8
	2.15	13·0	...	...	...	...	29·4	11·3	15·5
15/7	10.45	12·0	...	...	...	...	25·1	9·9	10·2
	—	13·1	..	...		...	27·0	11·5	12·0
16/7	10.0	8·4	...	...	...	...	29·5	28·3	8·9
	2.0	11·3	...		...	..	32·3	31·3	9·9
17/7	10.15	10·1	...	..			27·8	25·8	15·0
	2.15	11·9	...	..	...	...	30·1	29·8	13·3
20/7	11.0	11·6	...	...	...	..	30·6	12·1	12·1
	2.30	13·1	..	...		...	32·4	12·3	12·6
21/7	10.45	12·0	...	..	...	.	19·2	12·7	11·3
	2.30	13·4	...	...	...		29·4	13·3	12·1
22/7	10.30	12·1	..	...		...	30·3	11·7	12·1
	2.30	13·6	...	...	...	..	31·7	13·7	24·8
23/7	10.30	9·8	...	...	..	...	29·4	30·6	31·4
	2.30	13·7	...		...	...	32·5	31·7	32·6
24/7	11.0	12·1	...	..	...	...	30·7	27·3	30·6
	2.0	13·9	.	...			32·7	31·9	32·5
27/7	10.15	11·1	..	...		...	21·5	26·2	11·2
	2.45	13·8	...		...	...	31·3	30·1	13·6
28/7	10.15	10·6	..	...	...	...	28·4	20·8	10·8
	2.15	14·8	...	...	...	.	30·8	30·0	12·6
29/7	10.30	13·1	...	..	..	...	29·2	29·6	12·1
	2.30	15·5	..	...		...	32·6	31·8	13·3
30/7	10.30	12·4	...	...		..	26·4	26·8	11·5
	2.30	15·9	...	...			31·3	32·2	13·8
31/7	10.15	12·7	..	...	...	...	29·1	25·8	12·4
	2.15	15·1		..			31·1	30·2	13·8
4/8	10.15	13·3	...	...	...	..	30·6	22·7	...
	2.15	17·0	...	..		...	31·8	30·5	..

TABLE i.—*Continued.*

Date.	Time.	Air-temp.	Temperature of Echidna. No.1.	No.2.	No.3.	No.4.	No.4.	No.6.	No.7.
5/8	10.30	12·9	..	...	...	...	28·4	28·8	...
	2.15	17·1	...	...		...	27·4	31·9	...
6/8	10.30	14·9	...	...		...	23·7	29·3	...
	2.45	16·1	...	...	...	..	23·9	29·1	
7/8	10.45	14·2	...	...	..	...	14·4	27·9	...
	2.15	17·3	...	..	...	...	16·1	31·8	
10/8	10.30	12·9	...	...	...	...	dead	23·9	...
	2.15	15·7	...	...		...	..	31·3	...
11/8	10.15	11·8	...		...	...	...	26·9	...
	2.15	16·4	...		.	...	...	30·7	...
12/8	10.45	14·1	.	..	...	...	...	27·4	...
	—	—	...	...	...	...	...	—	...
13/8	10.45	13·3	..	...	...	...	..	29·8	...

In the case of Echidna No.1, it will be seen that, between April 30th, and May 22nd, its morning-temperature varied between 30·8° and 25·1°, except on May 19th, and 20th, when very low body-temperatures were recorded; its afternoon-temperatures varied between 32·5° and 27·6°C. On May 25th, the first definite hibernation was noticed, the temperature of the animal being very close to that of the air. Observation of the animal's temperature was at once suspended in order not to disturb the hibernation, but a partial awakening occurred on June 1st. The animal was again torpid next day, and died three days later.

In the case of Echidna No.2, between April 30th and June 12th, with the exception of June 4th, 5th, and 9th, when low body-temperatures were observed, the morning-temperatures of the animal varied between 32·1° and 25·1°C., the afternoon-temperatures between 33·4° and 30·8°C. The hibernation of this animal was very erratic; the first definite signs of it were observed on June 15th. The animal was torpid on June 15th, June 18th, and from June 30th to July 2nd. The temperature rose somewhat on July 7th, but fell again next day, and remained almost at the level of the temperature of the air till the death of the animal on July 10th.

Between April 30th and June 22nd, Echidna No. 3 showed no signs of hibernation. During this period its morning-temperature varied between 31·8° and 26·1°C., its afternoon-temperature between 31·8° and 34·0°C. On June 22nd, the animal commenced to hibernate, and was left undisturbed. On June 26th, the animal began to wake up, however, but became torpid again on the 28th. It was again left undisturbed, but woke again on July 5th. From July 9th, till the time of its death on July 29th, the animal hibernated continuously. This is the longest period of continuous hibernation shown by any of the Echidnas under my observation.

The temperature of Echidna No.4 behaved, on the whole, in rather an erratic fashion. From April 30th, to May 15th, its morning-temperature varied between 29·1° to 23·2°C., its afternoon-temperatures between 33·7° and 28·2°C. From May 16th, to May 21st, the temperature of the animal approached towards that of the air, the animal meanwhile becoming more and more sluggish, and finally quite torpid. Next day, the temperature of the animal rose suddenly to 28·8°C., but immediately began to fall again almost as rapidly, reaching the level of the temperature of the air on May 25th. The animal became torpid again and remained in this condition until its death on June 1st. As this animal was in a poor state of health when it came under observation, its temperatures are not regarded as normal.

Echidna No.5 is peculiar, as it showed only one short period of hibernation during the Winter, from June 2nd, to June 4th. For the remainder of this period, with the exception of the mornings of May 27th, and 29th, June 9th, July 19th, and 27th, and the three days preceding its death, the morning-temperature of the animal varied between 31·6° and 25·3°C., the afternoon-temperatures between 34·2° and 26·5°C, although only on one or two occasions were the lower values reached.

The morning-temperatures of Echidna No.6 remained between 30·9° and 27·1°C., the afternoon-temperatures between 33·5° and 30·4°C., from April 30th, to May 26th. On June 16th, the first definite signs of hibernation were observed. This animal hibernated for a day or two on five separate occasions during the Winter. These occasions were June 17th, July 2nd, 9th, and 10th, July 14th, 15th, and 16th, July 20th, 21st, and 22nd. It will be noticed that, between the periods of hibernation, the temperature of the animal rose very sharply to its normal values in the vicinity of 30°C. This animal was injured on one occasion (May 27th) while inserting the thermometer, and was left undisturbed for a few days to recover. It was still alive and in good health at the end of the period of the observations.

Echidna No.7 showed the first signs of hibernation on May 20th. Before that date, its morning-temperature varied between 30·2° and 26·1°C., its afternoon-temperature between 33·3° and 29·2°C. The first period of hibernation began on May 25th; the animal was left undisturbed, but became active again on June 1st. This animal hibernated on eight successive occasions during the Winter, most of its time during that season being spent in the torpid condition. The periods of hibernation were May 25th-29th, June 4th, June 9th-11th, June 15th, June 17th-22nd, June 23rd-30th, July 3rd-10th, July 14th-21st, and, finally, from July 27th till the death of the animal on August 1st.

TABLE ii.

Spring and summer temperatures of Echidna.

Date.	Time.	Air-temp.	Echidna 6.		Echidna 8		Echidna 9.		Echidna 10.	
			temp.	wt.	temp.	wt.	temp.	wt.	temp.	wt.
22/9	10.30	18·1	28·5		30·3		...		...	
	2.0	21·7	32·7	1590	33·1	1175	..	...	...	...
23/9	10.0	18·0	29·5		30·4		...		...	
	2.30	26·6	33·8	1570	33·6	1150	...	...	...	...
24/9	10.15	17·4	27·8		29·9		...		...	
	2.30	23·5	33·3	1560	33·7	1120	...	...	...	...
25/9	10.0	14·1	25·8		28·8				...	
	2.15	19·9	32·2	1600	33·0	1090	...	...	...	...
26/9	10.0	13·8	27·9		25·9		...		...	
	—	—	—		—		...		...	
28/9	10.10	16·9	27·5		24·6		...		...	
	2.30	22·2	32·4	1550	32·0	1030	...	...	...	...
29/9	10.30	15·7	28·4		31·0		...		...	
	2.15	21·4	32·8	1570	33·6	990	...	...	...	...
30/9	9.45	17·3	31·2		30·6		...		...	
	2.15	22·0	32·9	1500	32·4	960		...	...	...
1/10	10.30	18·1	29·8		dead		...		...	
	2.40	23·2	32·4	1780	...	.	...	...	...	...
2/10	10.30	15·4	28·0				29·9		...	
	2.45	16 1	30·8	1760	...	..	30 8	1890	...	...
6/10	10.20	18·2	30·4		...		29·0		...	
	2.30	25·4	33·5	1590	...		30·0	1970	...	..

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TABLE ii.—*Continued.*

Date.	Time.	Air-temp.	Echidna 6.		Echidna 8.		Echidna 9.		Echidna 10.	
			temp.	wt	temp.	wt.	temp.	wt.	temp.	wt.
7/10	10.15	18·9	30·2		...		30·0		...	
	2.30	25·3	33·2	1540	..	...	31·3	1980	...	...
8/10	10.30	20·3	30·3		..		30·8		.	
	2.30	21·2	32·6	1590	...	...	30·4	1930	...	...
9/10	10.30	23·4	29·5		..		30·2		...	
	2.30	29·6	33·5	—		...	31·5	—	...	...
12/10	...	.	...		...		...		...	
	2.55	21·6	33·2	1640	..	...	29·9	1850	...	...
13/10	10.25	18·8	29·6		...		30·3		..	
	2.20	24·2	33·5	1650	...	...	31·4	1800		...
14/10	10.30	22·6	31·1	1750	.		30·4	...	...	..
	2.25	22·3	33·1		.		29·7		...	
15/10	10.20	17·0	29·6		...		30·0		...	
	2.30	17·2	32·1	1740	...	...	32·0	1760	...	...
16/10	..	..	...		...		...		...	
	2.35	17·1	32·0	1800	...	..	30·4	1660	...	..
19/10	10.30	15·9	24·9		...		16·5		...	
	2.15	18·3	31·7	1650	...	...	17·2	1590	...	...
20/10	10.15	16·2	27·8		...		dead		...	
	2.30	17·6	32·2	1680	..	...	...	...	32·4	1680
21/10	10.25	18·2	29·4		...		..		29·9	
	2.10	22·5	33·2	1730	...	...	...	.	32·2	1640
22/10	10.30	19·6	29·4		...		.		29·0	
	2·15	36·8	32·5	1900		...	.	...	31·4	1610
23/10	10.0	19·9	28·3		...		...		26·7	
	2.10	26·8	33·2	1860	...	..	...	...	33·2	1570
26/10	10.30	28·9	31·9		...		..		29·8	
	2.20	30·4	34·0	1690	.		..	...	32·0	1560
27/10	10.15	22·8	29·8		...		...		28·3	
	2.20	27·9	33·5	1760	...	...	...	...	33·5	1630
28/10	10.30	19·3	29·2		...		...		28·4	
	2.30	20·2	32·3	1740	...	...	...	..	32·1	1570
29/10	10.30	21·2	—		...		...		30·3	
	2.15	24·9	33·3	1800	...	...	...	.	33·1	1590
30/10	10.25	27·4	30·9		...		...		31·5	
	1.45	34·2	33·9	1820	...	...	...	..	33·0	1620
2/11	10.20	20·5	31·1		..		...		25·6	
	2.15	21·9	32·7	1740				...	31·2	1530
3/11	10.30	22·3	30·9		...		..		24·4	
	2.25	23·7	33·1	1870	...	...	...	...	32·2	1560
4/11	10.10	20·9	29·8		...		...		29·3	
	2.25	25·6	33·4	1840	...	...	...	...	32·2	1550
5/11	10.15	23·8	30·7		...		...		29·6	
	2.10	28·4	34·0	1860	.	..	...	...	31·9	1530
6/11	10.20	22·9	30·2		...		...		29·4	
	2.40	24·4	33·7	1820	...	...	...	...	33·0	1490
9/11	10.35	25·0	32·4		...		...		31·6	
	2.30	22·2	33·3	1760	...	...	...	...	32·2	1420

TABLE ii. *Continued.*

Date.	Time.	Air-temp.	Echidna 6.		Echidna 8.		Echidna 9.		Echidna 10.	
			temp.	wt.	temp.	wt.	temp.	wt.	temp.	wt.
10/11	10.25	25·0	31·4		...		...		30·0	
	3.0	29·2	33·9	1900	...	...	...	...	32·7	1440
11/11	11.10	19·6	30·7		...		...		27·4	
	2.30	20·8	32·4	1950	...	...	...	...	30·6	1420
12/11	10.20	21·6	28·3		...		...		29·3	
	2.20	22·7	32·4	1860	...	...	...	...	31·2	1360
13/11	10.0	22·8	31·7		...		...		27·8	
	2.30	28·3	33·7	1850	...	...	...	...	32·2	1330
16/11	10.15	25·1	32·5		...		...		30·4	
	2.35	28·9	33·8	1810	...	...		...	31·7	1280
17/11	9.50	25·5	32·1		...		...		32·2	
	2.20	24·2	32·6	1950		...	...		31·9	1270
18/11	10.5	22·2	30·6				...		30·3	
	2.40	23·1	31·8	2000	...	...	...	...	30·9	1210
19/11	10.5	21·4	...		...		...		27·0	
	2.15	24·3	31·4	1910	...	...	...	...	28·6	1150
20/11	10.20	25·8	31·1		...		...		dead	
	2.25	27·4	34·0	1920	...	...	...	...	...	...
23/11	10.0	22·9	33·2		...		...		...	
	2.30	24·2	33·8	1760	...	...	...	...	...	...
24/11	10.5	24·2	31·8		...		...		...	
	2.25	28·3	33·7	—	...	...	...	...	...	...
25/11	9.55	24·3	31·1		...				...	
	—	—	—	1820	...	...	...		...	...
27/11	10.20	20·5	28·9		...		...		...	
	3.15	22·6	33·0	1910	...	...	...	...	...	...
30/11	—	—	—		...		...		...	
	2.0	21·6	33·0	1750	...	...	...	...	...	...
1/12	10.10	20·8	30·1		...		...		...	
	2.35	27·0	33·7	1820	...	...	...	...	...	...
2/12	10.0	22·3	28·7		...		...		...	
	2.35	26·5	33·5	1790	...	...	...	...	...	...
3/12	10.15	21·8	30·0		...		...			
	2.35	22·6	33·0	1820	...	...	...	...	...	...
4/12	10.35	21·2	29·4		...		...		...	
	2.15	28·3	33·5	1830	...	...	...	...	...	...
7/12	11.0	20·5	31·0		...		...		...	
	2.25	21·6	32·6	1730	...	...	...	...	...	...
8/12	10.40	19·7	28·7		...		...			
	2.35	23·9	31·9	1790	...	...	...	...	...	...
9/12	10.10	22·3	30·6		...				...	
	2.20	28·5	33·5	1770	...	...	...	...	...	...
10/12	10.35	22·9	30·5		...		...		...	
	2.30	24·9	33·9	1840	...	...	...	...	...	...
11/12	10.30	24·2	31·5		...		...		...	
	2.25	29·6	33·4	1850	...	...	...	...	...	...
14/12	9.45	23·4	31·1		...		...		...	
	3.30	25·4	33·7	—	...	...	...	...	...	...

TABLE ii.—*Continued.*

Date.	Time.	Air-temp.	Echidna 6.		Echidna 8.		Echidna 9.		Echidna 10.	
			temp.	wt.	temp.	wt.	temp.	wt.	temp.	wt.
15/12	10.40	27·3	32·7		..		...		...	
	2.35	34·1	33·9	2100	...	...	.	..	..	...
16/12	9.40	25·3	29·4		...		...		...	
	2.30	32·5	32·4	2010	..	...	...	...	...	..
17/12	10.10	24·8	31·9		...		...		...	
	2.30	30·2	33·1	1920	...	...	...	..	...	...
18/12	9.55	22·2	30·6		...		...			
	2.30	23·0	33·3	1900		...	...	...	...	...
21/12	9.50	20·8	29·1		...		..		...	
	3.0	20·6	31·7	...	...	...	...	...	..	...

In Table ii., a record of the weight of the animals has been added, so that some idea may be gathered of the general state of their health during this period of observation.

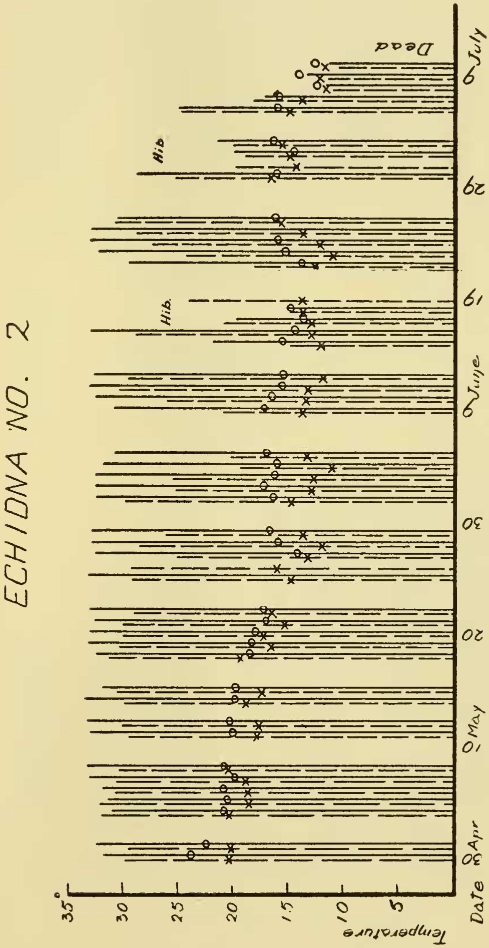
The morning-temperatures of Echidna No.6 will be seen, from the above Table, to have varied between 33·2° and 25·8°C., the afternoon-temperatures between 34·0° and 30·8°C. The weight of the animal also showed very large fluctuations, its lowest value being 1540 gms., its highest 2100 gms. The weight, on the whole, increased, however, and the animal was still living and in good health at the end of the period of observation.

Echidna No.8 lived only a short time while under observation. During this time, its weight steadily fell. Its morning-temperatures varied between 31·0° and 24·6°C., its afternoon-temperatures between 33·8 and 32·0°C.

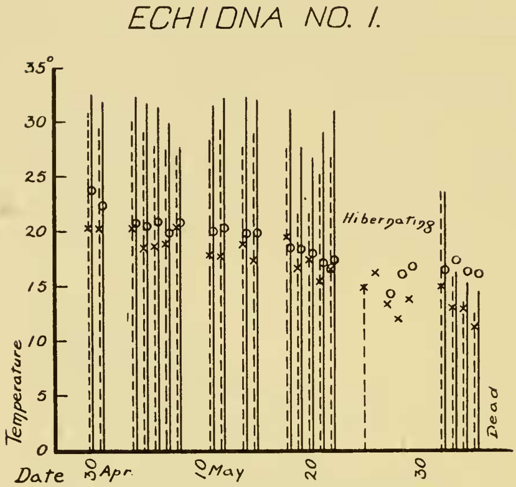
Echidna No.9 also did not live long, and its weight, too, steadily fell. Its morning-temperatures varied between 30·8° and 29·0°C., its afternoon-temperatures between 31·5° and 29·7°C., except on the last day, when the animal was dying, and its temperature was almost at the level of that of the air.

Echidna No.10 also decreased in weight during the period of observation, although it lived about thrice as long as Nos.8 and 9. Its morning-temperatures varied between 32·2° and 24·4°C., its afternoon-temperatures between 33·5° and 30·6°C.

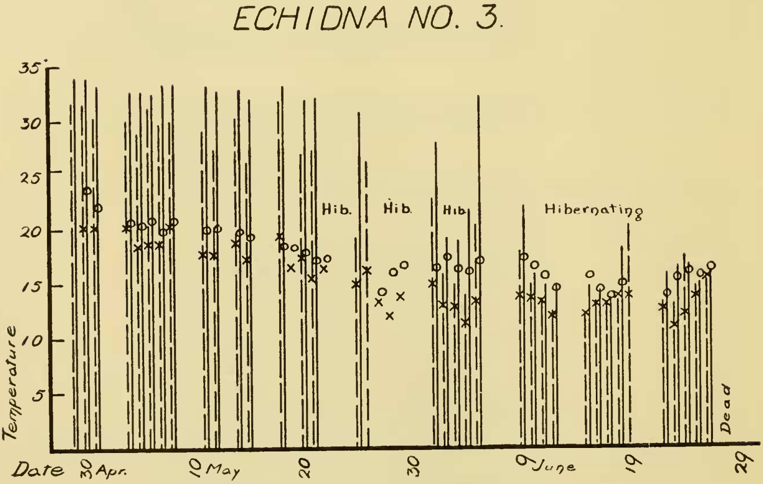
The observations recorded in the above Tables, with the exception of those made on Echidna No.4, have been plotted out graphically in order to render their meaning more evident. In the accompanying diagrams (Text-figs.1-8), the temperatures are represented by vertical lines, the heights of which are proportional to the values of the corresponding temperatures. Morning-temperatures are represented by discontinuous lines, afternoon-temperatures by full lines. The points corresponding to the levels of the temperatures of the air are marked on the ordinates for the temperatures of the animals by crosses in the case of morning-temperatures, and by circles in the case of afternoon-temperatures.



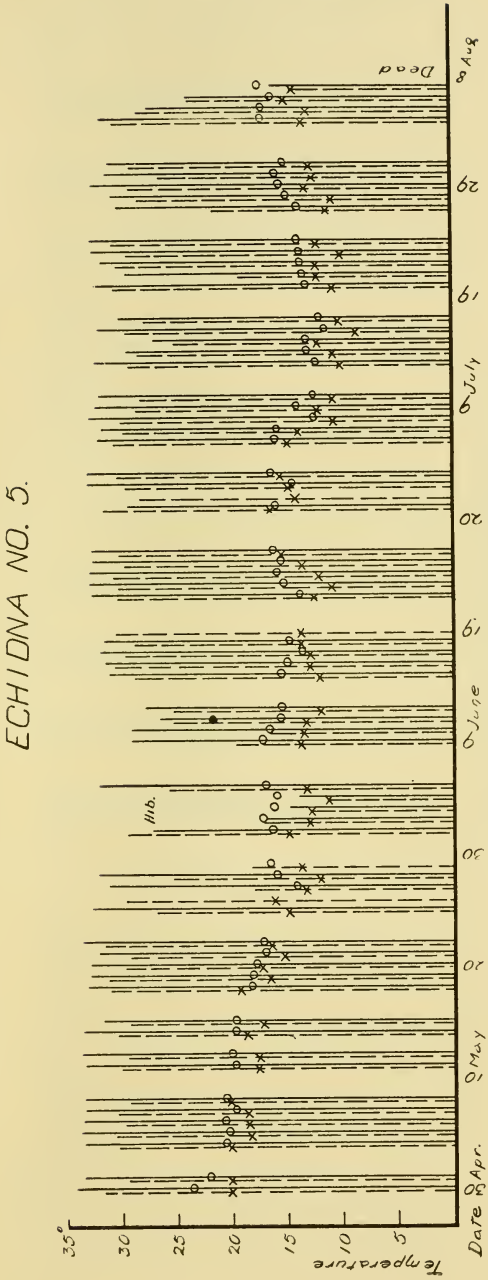
Text-fig.2.—Autumn and Winter temperatures.



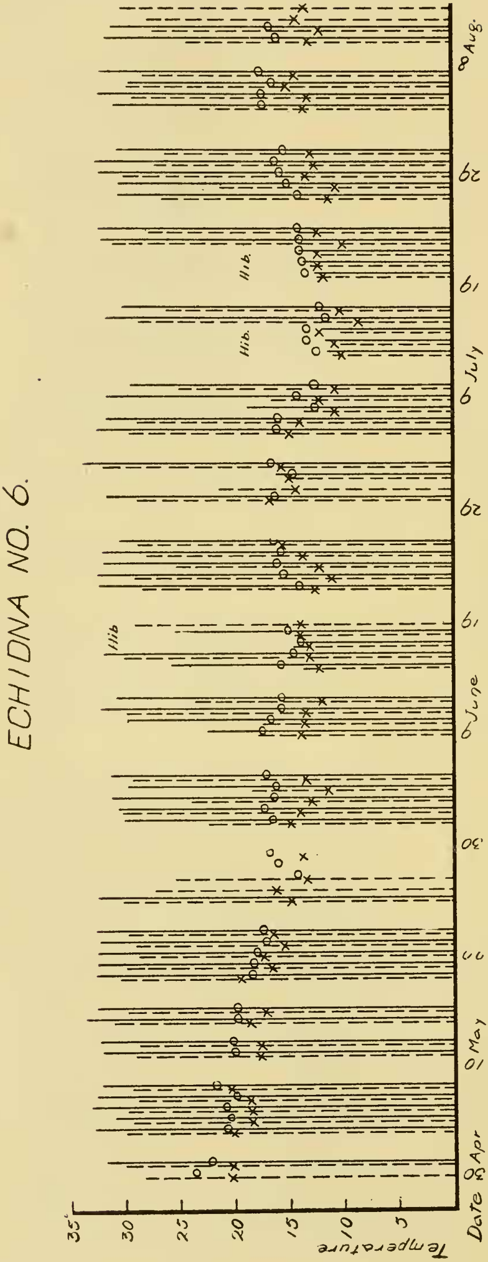
Text.fig.1.—Autumn and Winter temperatures.



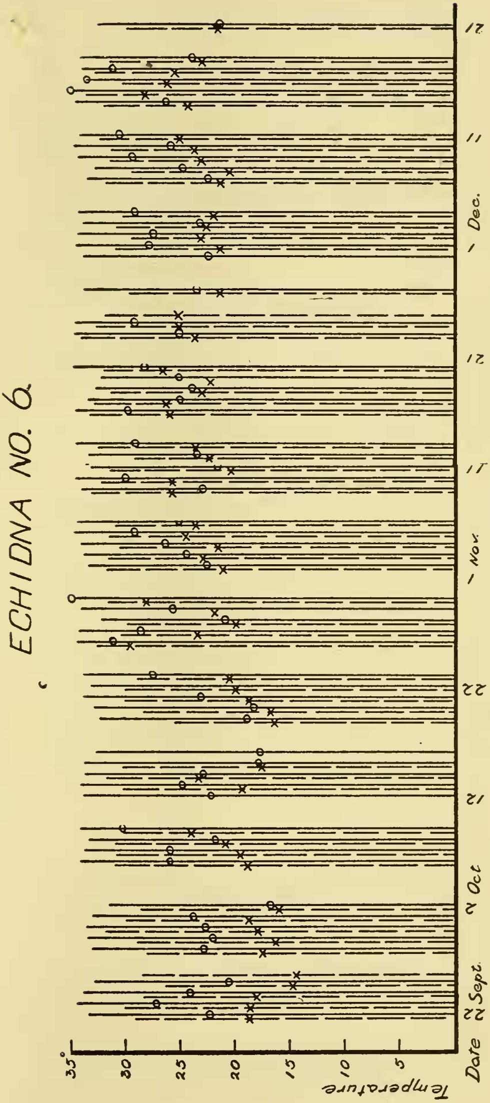
Text-fig.3.—Autumn and Winter temperatures.



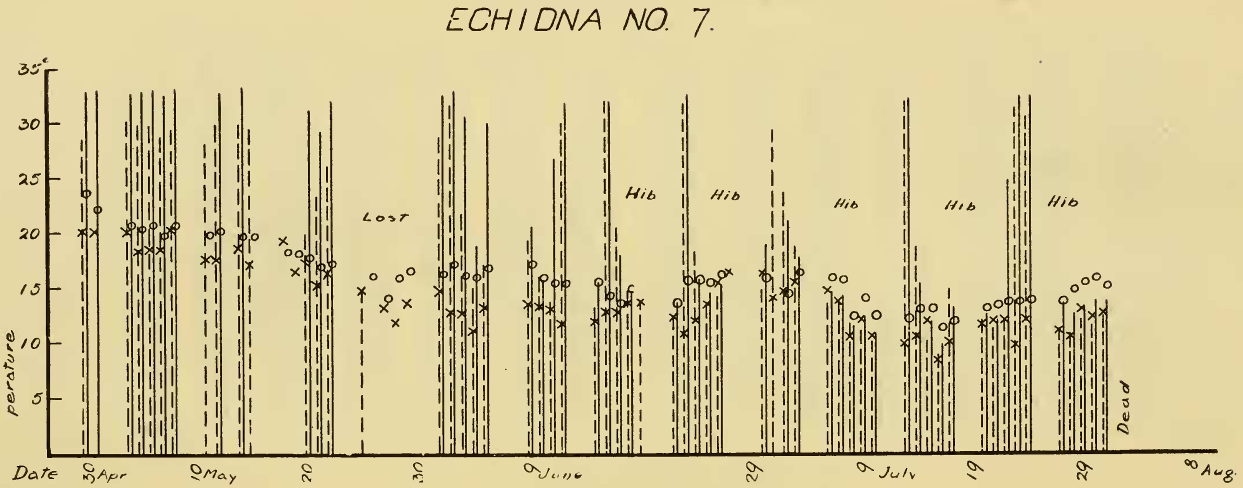
Text-fig. 4.—Autumn and Winter temperatures.



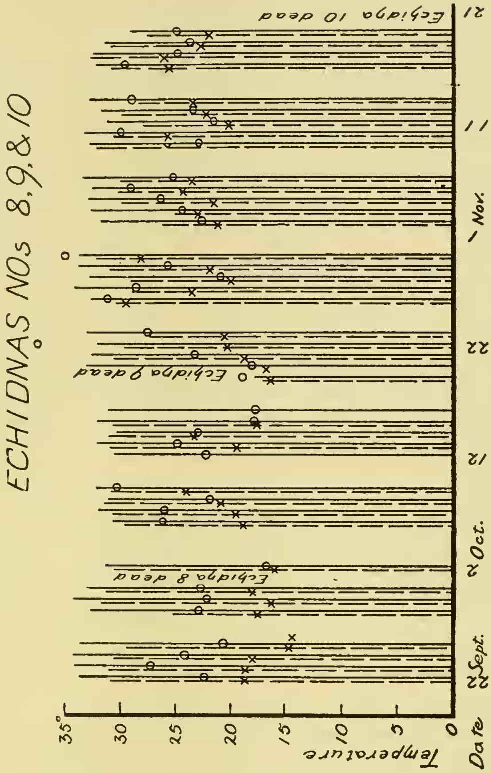
Text-fig. 5.—Autumn and Winter temperatures.



Text-fig. 6.—Spring and Summer temperatures.



Text-fig. 7.—Autumn and Winter temperatures.



Text-fig. 8.—Spring and Summer temperatures.

The above series of observations was made, as will be seen, during two periods of the year. The first period extended from April 30th to August 13th, 1914, 105 days, and comprised the end of Autumn and the greater part of Winter. The second period extended from September 22nd to December 21st, 1914, 90 days, and comprised the greater part of Spring and the beginning of Summer. For the first series of observations, Echidnas Nos. 1, 2, 3, 4, 5, 6, and 7 were used; for the second series, Nos. 6, 8, 9, and 10.

As the behaviour of the animals, with regard to their temperature, was considerably different in the winter-portion of the first period from that in the autumn-portion of it, and in the second period, it will be convenient to consider first the observations obtained during the Winter separately.

Hibernation of Echidna.—As previously stated, under the conditions under which I observed Echidna, its hibernation was of a very fitful nature. This fact is well exhibited by the sudden falls and rises of temperature shown in the diagrams giving the winter-temperatures. During the periods of hibernation, the temperatures of the animals remained only slightly higher than the external temperature, following the variation of this like the temperature of a cold-blooded animal. The instances in which the temperatures of Echidna are shown to be actually lower than the external temperatures are due to the occurrence of rises of the latter so rapid that the animals have not warmed-up quickly enough to follow them. The diagrams also show how great are the individual differences between the animals as to the extent to which they hibernate during Winter, the only common feature being the fact that none of them ever hibernated continuously for more than a few days at a time. The longest period of hibernation shown extended over about ten days; the average period, however, was only two or three days. During these periods, the animals lay inert while undisturbed, and showed no visible respiratory movements. If moved and placed in an awkward position, they very slowly readjusted themselves.

No doubt the unnatural conditions, under which the animals were living, had much to do with the intermittence of their hibernation. The taking of an animal's temperature, *per rectum*, twice a day, must have a rather disturbing effect, although specimens which were purposely left undisturbed, during periods of hibernation, did not remain torpid any longer than others whose temperatures were regularly taken.

The behaviour, during Winter, of the Echidnas under my observation was markedly different from that of the animals observed by Martin, who states that "during Winter, Echidna abandons all attempts at homœothermism and hibernates for four months." The fact that the Winter of Melbourne (where Martin's observations were made) is rather colder than that of Sydney, the average midwinter temperatures being 9·5° and

12·2°C., respectively (Hunt, *loc. cit.*), may account for the fact in part, but, apparently, not altogether, as an examination of the diagrams and tables will show that the animals were sometimes awake and active at temperatures lower than those at which they were, at other times, torpid. Temperature seems, therefore, not to be the only factor concerned in the bringing on and maintenance of hibernation, as has also been supposed in the case of European hibernants.

With regard to the rate at which the animals enter into or emerge from a state of hibernation, no very detailed information can be gained from the tables and diagrams, as the temperatures were not observed at frequent enough intervals. The large falls of temperature, indicating the entrance of an animal into a state of hibernation, generally occurred between an afternoon-observation of the temperature and the succeeding morning-observation. Falls of temperature of as much as 16°-17° occurred in this period of twenty hours, as in the case of Echidna No.6, on June 16th-17th, and of Echidna No. 7 on June 3rd-4th. Between the morning- and afternoon-observations, a period of about four hours, comparatively sudden rises of temperature occurred as the animals awoke from hibernation. For example, in the case of Echidna No.6, on June 15th, a rise of 12·0° occurred in the above interval of time; and, in the case of Echidna No.7, a rise of 13·8° occurred on June 5th, in the same period.

Relation between temperature of Echidna and temperature of air.—Let us consider now the temperature of Echidna during the periods in which no hibernation occurred, Autumn, Spring, and Summer. It will be seen that, during these periods of observation, firstly, the morning-temperature of the animals was, with only one or two exceptions, lower than the afternoon-temperature; and, secondly, that, although the morning- and afternoon-temperatures each showed variations considerably greater than are met with in the case of human beings, yet these variations seem to have occurred about a sort of mean value; and we may therefore speak of these temperatures as having certain average or mean values, always bearing in mind the very doubtful significance of any average or mean figure as applied to living organisms. In the following Table, the average morning- and afternoon-temperatures for several individual Echidnas, and for the whole number in the Table are given for the autumn-period, *i.e.*, the period before hibernation.

TABLE iii.

Average Autumn-temperatures of Echidna.

Echidna	Temperature Morning	Temperature Afternoon	No. of obs.
2	30·2°	32·5°	18
5	30·2°	33·2°	16
6	29·4°	32·1°	17
7	29·5°	32·9°	10
Average	29·9°	32·7°	61

It will be seen that the individual averages do not differ much from one another. Single observations, however, may differ as much as 3° from the average values. The average morning- and afternoon-temperatures from 61 observations distributed over four animals are shown to be 29·9° and 32·7°C. respectively. The average temperature of the air for this period was about 18°C.

In Table iv., are given the average morning- and afternoon-temperatures for individual Echidnas, and for the whole number in the Table for the Spring- and Summer- period, *i.e.*, after hibernation.

TABLE iv.

Average Spring- and Summer-temperatures of Echidna.

Echidna	Temperature Morning	Temperature Afternoon	No of obs.
6	30·1°	32·9°	60
8	28·9°	33·1°	8
9	30·1°	30·8°	9
10	29·0°	31·9°	23
Average	29·4°	32·2°	100

In this table, too, it will be seen that the individual averages do not differ greatly from one another, although the differences shown are greater than in Table iii. The collective average morning- and afternoon-temperatures, obtained from 100 observations distributed over four animals, are, in this case, 29·4° and 32·2°C., respectively, values slightly lower than those given in the preceding Table, although the average temperature of the air for this period was about 23°C., or 5° higher than in the autumn-period. The differences from the average values shown by single observations are rather greater than was the case with the autumn-temperatures, differences of about 5° occurring in a few cases. This may possibly be due, in part, to the fact that the health of the animals examined in Spring and Summer, with the exception of that of No.6, was not so good as that of those examined in Autumn. The former animals lived only 1-3 weeks while under observation, whereas the latter lived considerably longer, on the whole. It is to be noted, however, that the variations in the temperature of Echidna No.6, which has survived all the others, were as great during the spring-period as those of the animals which died.

It has been seen that, outside of the winter-period, the morning-temperature of Echidna was almost invariably lower than the afternoon-temperature; the average difference for the whole of the observations was 2·8°C., but there were considerable variations from this value. It will be seen, too, that, in the great majority of cases, the external temperature was also higher in the morning than in the afternoon. In spite of this general agreement in the direction of the changes of the temperature of the air and that of the changes of the temperature of the animals, the grounds do not seem sufficient for concluding immediately that the variations in the temperature of the animal are due to those of the temperature of the air. In the first place, there were several instances in which the temperatures of the air in the morning were greater than in the afternoon, and yet the temperatures of the animals increased towards the afternoon in the usual way. These instances are collected together in the following Table.

TABLE V.

Relation of temperature of Echidna to temperature of air.

Date.	Temperature of air		Temperature of air	
	Morning	Afternoon	Morning	Afternoon
18/5/14	19·3°	18·3°	27·4°	31·0°
			31·2°	32·0°
			31·8°	33·2°
			31·0°	33·1°
			30·3°	32·5°
30/6/14	16·5°	16·0°	29·3°	31·3°
			31·6°	29·3°
2/7/14	14·8°	14·5°	29·6°	33·0°
14/10/14	22·6°	22·3°	31·1°	33·1°
			30·4°	29·4°
9/11/14	25·0°	22·2°	32·4°	33·3°
			31·6°	32·2°

As will be seen from the above Table, there were only two occasions on which a reversal of the direction of change of the temperature of the air was accompanied by a similar reversal in the direction of variation of an animal's temperature, and, on each of these occasions, this reversal was shown only by one of two animals under observation.

In addition to these cases in which the temperature of the air fell, instead of rising, between morning- and afternoon-observations, there were many occasions on which the rise of the temperature of the air was less than that of the temperature of the animals. Further, there were four occasions on which, although the temperature of the air rose between morning and afternoon, that of an animal fell in the same interval of time; and these do not include those cases where erratic behaviour of the temperature of an animal was due either to the onset or to the close of a period of hibernation.

From the above facts, therefore, it seems that the daily variation of the temperature of Echidna does not entirely depend upon that of the temperature of the air, but is, in part, of the same nature as the daily variation observed in the case of other mammals (of man in particular), which is regarded as quite independent of the variations of the temperature of the air, and which, as in the case of Echidna, consists of an increase, though a much smaller one, between morning and afternoon. The magnitude and unevenness of the daily variation in the case of Echidna are quite in keeping with the general behaviour of its temperature. It must be remembered, too, that temperatures were observed only at two times of the day, and these may not have coincided with the extremes of variation of the animals' temperatures.

If one considers now the relation of a series of morning- or of afternoon-temperatures to the corresponding temperatures of the air, it will be found that the variations of the former sometimes take place in the same direction as those of the latter, and at other times in the opposite direction. The prevailing tendency is, however, for the variations of the air-temperatures and of the body-temperatures of the animals to be in the same direction, so that there seems to be some connection between the two. This view is further supported by the comparison of the mean autumn-temperatures of Echidna No.6, with the mean spring- and summer-temperatures of the same animal. The air-temperatures during Autumn were considerably lower than those during Spring and the beginning of Summer. The average temperatures of the animal were: Autumn, morning, 29·4°, afternoon, 32·1°; Spring and Summer, morning, 30·1°, afternoon, 32·9°C. Over these fairly long periods, then, higher temperatures of the animal were, as a rule, associated with higher air-temperatures, although the evidence of any causal connection between the two is not very strong. It will be remembered, however, that the average morning- and afternoon-temperatures of several animals (Tables iii. and iv.) were slightly higher in Autumn than in Spring.

Summary. —(1). During the winter-months, the Echidnas under observation hibernated intermittently, their temperatures approximating to those of the air during the periods of hibernation.

(2). Outside of the periods of hibernation, these Echidnas maintained a temperature which was fairly constant (30-33°C.), although lower than that of other mammals. Echidna, therefore, is a true homoiothermal animal.

(3). The temperature of these Echidnas showed a daily variation, which seemed to be, to some extent, independent of the variations of the external temperature.

(4). Apart from the bringing on of hibernation, there is an indication that change of the external temperature has an effect, although not a simple or immediate one, on the body-temperature of Echidna, as the average temperature of an animal in Spring was slightly higher than that of the same animal in Autumn.

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